**Range Mgmt. & Agroforestry 34 (1) : 26-32, 2013**
**ISSN 0971-2070**

# Inter-specific association of herbaceous vegetation in semi arid Thar desert, India

**Manish Mathur* and S. Sundaramoorthy**
Plant Ecology Laboratory, Jai Narain Vyas University, Jodhpur, India
*Present Address: Central Arid Zone Research Institute, Jodhpur, Rajasthan, India
*Corresponding author email: ravi_mm2099@yahoomail.com;eco5320@gmail.com
Received: 9th August, 2012 Accepted: 20th June, 2013

**Abstract**
Temporal variations in inter-specific association of the herbaceous guild at 12 semi-arid sites in the Thar desert, India were studied using values of variance ratio and chi square test. According to the seasonal species richness, it was possible to compare 406, 300 and 153 species pairs for the pulse, inter-pulse and non-pulse events, respectively. Based on the variance ratio overall negative associations were recorded during respective events. The positive to negative ratios for the respective seasonal interactions were 0.65, 0.5 and 0.44. Interactions between *Blepharis sindica -Lasiurus sindicus* and between *Lepidagathis cristata - Sonchus asper* were positive for all the three events. Based on the Jaccard values, 13 absolute, 30 complete and 17 negative significant association types were identified. This study reveals that in limited and fluctuating environment mixing of perennial -annual herb system is more adaptable for the temporal fluctuations. Sixteen different regression equation were developed and based on the path analysis richness, Shannon and Weaver index, electric conductivity and soil Phosphorus were recognized as indicator factors controlling the types of associations.

**Key Words**: Ecosystem services and functioning, Forage, Grassland Management, Jaccard index, Landscape management, PCA, Path analysis, Species association

## Introduction

The living organisms interact with each other through various mechanisms and their interactions plays important role in shaping the structure and function of ecological communities and the ecosystem as a whole. Strength of species interactions, patterns that occur between species and mechanism that cause interaction across space and time in natural ecosystems are challenging but could be used in predicting the outcome of change in species composition. Depending on whether or not two species select or avoid the same habitat, have some mutual attraction or repletion, or do not interact at all, could give birth to a particular biotic association. This association may be positive, negative or negligible. The combination of negative and positive interactions operating between plant species appears complex, wide spread in nature, and is not restricted to particular communities or biomes (Callaway, 1995). Several hypothesis suggest that the importance of facilitation (positive association) among plants may increase with decreasing environmental harshness, while competition (negative association) between plants trend to increase in less stressful environment (Sanjerehei *et al.,* 2011). Studies of association (Fajardo *et al.,* 2008), covariation (Callaway, 1994), segregation (Getzin *et al.,* 2006) are the approaches widely used to assess the type of interaction in plant communities.

Plant productivity in desert is extremely variable from year to year and could be attributed to variation in rainfall (Noy-Meir, 1973) or to more variables (Le Houerou *et al.,*1988). Sen (1966) described 44 associations in 15 alliances and 8 orders for the vegetation in and around the Jodhpur, the gateway to Great Indian Desert. Bharucha (1975) recognized 13 associations in western Rajasthan and each association was described with reference to (a) the characteristic species, (b) facies species of hygrophilous, sandy, gravely, or rocky and ruderal association (c) species of alliances, (d) species of order (e) companion species and (f) escapers.

The objectives of this research were (1) to determine impact of temporal fluctuation with respect to type, strength and modification of the balance between positive and negative interaction among herbaceous vegetation in the semi arid part of the Indian Thar desert and (2) to assess underlying factors affecting the type of interaction.

**Materials and Methods**

For vegetation studies, 12 natural sites were selected in and around Jodhpur. Their coordinates, habitat types and dominant herbaceous species are presented in table 1. At each site, the herbaceous vegetation (woody/ non-woody annual or perennial herbs) was sampled for density in 10 quadrate of 1x1m size (Kent and Cooker, 1992). The samplings were carried out at three events namely Pulse (rainy, July), inter-pulse (winter, December) and non-pulse (summer, June) events.

The study of species association involved two distinct components. First statistical test of the hypothesis that evaluating the association at predetermined probability level during various events and, the degree of strength of the association is the second part. The measurement of degree of association between pairs of species especially the species of interest with other species may be an important tool for valuable ecological information for particular plant species. Janson and Vegelius (1981) recommended three different indices, namely Ochiai, Dice and Jaccard indices for pair association and these indices were calculated as per Ludwig and Reynolds (1988).

Numerical abundance recorded at each site during various sampling time were converted to presence-absence data where the presence of the species was indicated by 1 and the absence was indicated by 0 (Ludwig and Reynolds, 1988). The overall positive or negative association was declared based on value of variance ratio. If the value of variance ratio is less than 1, it indicates negative association whereas a value of 1 or more than 1 indicates positive association. Further the deviation from 1 was computed with test statistic (W) *i.e.* the product of sampling unit and variance ratio. The significance of interaction between the species pairs was declared based on chi-square test.

Multivariate analysis was performed with 'Xlstat (free version) software'**.** Exploratory Factor Analysis (Principal Component Analysis) was carried out as a data reduction techniques. Various parameters related with distribution pattern of whole community (random, clumped and uniform), edaphic (Organic carbon, nitrogen, phosphorus, moisture, pH and electric conductivity), community dynamics (richness Shannon and Weaver Index, Simpson index and Evenness) during pulse, inter-pulse and non-pulse events were utilized. Pearson correlation coefficient was used for PCA analysis. Appropriate regression equations were selected on the basis of probability level significance and higher $R^2$ value. This path analysis was carried out with 'Curve Expert' software.

**Results and Discussion**

During the samplings, a total of 33 herbaceous species were recorded that belonged to 19 families dominated by Poaceae (8) followed by Boraginaceae and Acanthaceae (3). Our results indicate an overall negative association between species as suggested by the values (< 1) of variance ratio during all the events (0.489 pulses; 0.341 inter-pulses; and 0.745 non-pulses). Furthermore, the values of the test statistic (W) were 5.83; 4.09 and 7.47 during various events. The values of test statistics obtained during pulse and non-pulse events lies within the 90% probability limits of chisquare distribution, suggesting that there were non-significant association between 29 species during pulse and 18 species during non-pulse events. However, the value of W during inter-pulse season (4.09) lies outside the range of chi-square distribution indicating significant association among 25 species (Table 2).

From the above analysis, we have obtained 406, 300 and 153 pairs during various temporal events. The ratios of positive to negative associations were 161/245; 101/199 and 47/106, indicating the greater degree of negative association at various temporal instances. The chi-square results further revealed that significant species pairs were few in number. 31 (19 positive and 12 negative), and 19 (14 positive and 5 negative) significant pairs were recorded during pulse and inter-pulse events, respectively. On the contrary, during non-pulse event (non-pulse), no statistically significant negative pair was obtained (Table 2).

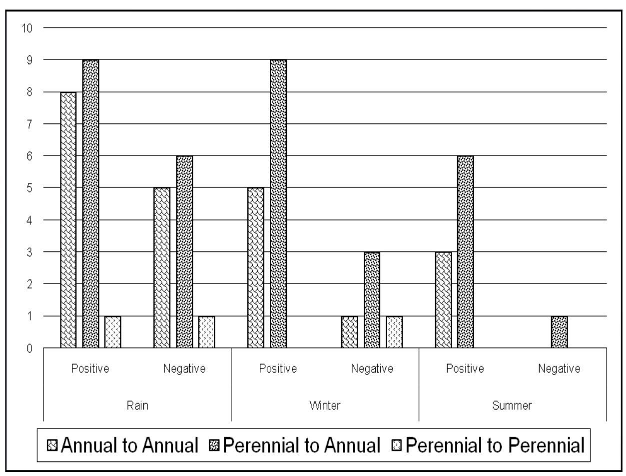


**Figure 1.** Habit of the statistically significant pairs

**Table 1.** Habitat types and other attributes of sampling sites

| Site No. | Coordinates N | Coordinates E | Habitat | Sub-Climax species (arrange in descending order of RIV) |
|---|---|---|---|---|
| 1 | $26^0$ 12' 29.5'' | $73^0$ 04' 24.8'' | Hummock undulating terrains | *Cenchurs biflorus, Indigofera cordifolia, Aristida funiculata* |
| 2 | $26^0$ 15' 1.8'' | $73^0$ 59' 29.8'' | Old alluvium plains | *C. biflorus, Lasiurus sindicus* |
| 3 | $26^0$ 12' 48.4'' | $73^0$ 4' 7.8'' | Old alluvium plains (no tree cover) | *Dactyloctenium sindicum Eragrostis cilliaris* |
| 4 | $26^0$ 11' 33.4'' | $73^0$ 3' 6.1'' | Younger alluvium and river bed terrain | *E. cilliaris, Lepidagathis cristata* |
| 5 | $26^0$ 14' 47.01'' | $73^0$ 0.0' 58.9'' | Old alluvium plains | *D. sindicum, I. cordifolia* |
| 6 | $26^0$ 14' 12.4'' | $73^0$ 01' 24.2'' | Old alluvium plains protected | *E. cilliaris* |
| 7 | $26^0$ 21' 54.5'' | $73^0$ 03' 48.9'' | Younger alluvium and river bed terrace | *E. cilliaris, A.funiculata* |
| 8 | $26^0$ 12' 33.7'' | $73^0$ 4' 8.4'' | Old alluvium plains | *E. cilliaris, D. sindicum* |
| 9 | $26^0$ 14' 31.6'' | $73^0$ 01' 21.1'' | Old alluvium plain | *E. cilliaris, Euphorbia granulate* |
| 10 | $26^0$ 18' 47.0'' | $72^0$ 60' 35.1'' | Piedmonts area | *I. cordifolia, A funiculate, C. biflorus* |
| 11 | $26^0$ 17' 2.5'' | $72^0$ 56' 5.9'' | Younger alluvium plain | *E. cilliaris, D.sindicum I. cordifolia* |
| 12 | $26^0$ 20' 58.9'' | $73^0$ 3' 57.2'' | Hummocky undulating terrains | *C. biflorus, D. sindicum I. cordifolia* |

**Table 2.** Number of species, their interspecific association values, total and significant species pairs

| Events | Total number of species recorded | Variance Ratio | Value of test statistic (W) | Total no. of pairs obtained | Number of association* | | Distribution pattern | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Positive | Negative | Random | Clumped | Uniform |
| Rain | 29 | 0.489 | 5.83 | 406 | 161 (19) | 245 (12) | 8.3 | 833.3 | 8.3 |
| Inter-Pulse | 25 | 0.341 | 4.09 | 300 | 101 (14) | 199 (5) | 25 | 50.0 | 25.0 |
| Non-Pulse | 18 | 0.745 | 7.74 | 153 | 47 (10) | 106 (0) | 16.66 | 25.0 | 58.3 |

*Values in parenthesis indicate statistically significant associations.

The positive interactions between *Blepharis sindica* - *Lasiurus sindicus* and between *Lepidagathis cristata* and *Sonchus asper* were the rule existing during all three events, whereas positive interaction between *B. sindica* - *Corchorus trilocularis* occurred only during pulse and inter-pulse events. The negative interaction of *Tephrosia purpurea* with *B. sindica,* L. *sindicus* and *C. trilocularis* were recorded during pulse and inter-pulse period, and the similar result was recorded between *Cenchrus biflorus* and *Corchorus depressus* (Table 3). The statistically significant pairs (both positive and negative) were further differentiated based on plant habit and it revealed greater positive and negative interactions between perennial and annual herbs as compared to only seasonal annuals. It is also evident that the number of positive and negative interactions among annual- annual plants and negative interaction between perennial - annual decreased from pulse to non pulse event (Pulse to non-pulse). However, the number of positive association of perennial – annual were maintained from pulse to inter-pulse season (Fig.1).

Understanding and predicating the dynamics of multispecies system generally require estimates of interaction strength among species. Measuring interaction strength is difficult because of the large number of interaction in any natural system; long term feed back, multiple pathways of effect between species pairs and possible nonlinearities in interaction (strength function). Spatial and temporal variations may affect the degree of interaction strength. Previous studies suggest that distribution of interaction strength tend to be skewed *i.e.* towards few strong and many weak interactions (Wootton and Emmerson, 2005). Ahmad *et al.,* (2008) reported that physical and chemical properties of each site had their own impact on species association but season effects, particularly temperature and rainfall during different season of the year were more pronounced.

Abiotic factors are often thought to be the predominant forces shaping desert plant communities. Both positive and negative interactions between plants are frequently observed in desert. Jochen and Bruce (2002) studied the impact of positive and negative plant interaction in the spatial structure of a desert community. They hypothesized that negative interspecific interaction appear to cause spatial segregation of *Ambrosia dumosa* plant, while a combination of positive and negative interaction apparently contribute to the directional association between *A. dumosa and Acamptopappus sphaerocephalus.* They conclude that plant interaction in the Mojave Desert affecting the shape of community structure in two dimensions by influencing the distance and in which directions to their neighbour plants can grow and survive.

**Measuring the degree of strength of association**

Janson and Vangelius (1981) reviewed 20 different indices use for measuring the degree of association strength. Each index had its own advantage and disadvantage. The Jaccard coefficient is the only 1 of 3 that was recommended by Hubalek (1982) and Turner *et al.,* (2004). Further Ludwig and Reynold (1988) concluded that for most ecological data, it is better to ignore the joint absence and recommended Jaccard coefficient which make no use of joint absence. Turner *et al.,* (2004) interpreted the type of association based on the value of Jaccard index. According to them 0, 0.33, 0.5 and 1 values of Jaccard index represent the negative, independent, complete and absolute association, respectively. A complete association is one in which all occurrences of one species are at a subset of the sites where the other species is present. Thus, a complete association implies that either b=0 or c=0. Based on the Jaccard values, 13 absolute, 30 complete and 17 negative significant association types were identified (Table 3). In the present investigation, the interaction strength between *B. sindica – L. sindicus* and between *L. cristata* and *S. asper* did not fluctuate temporally. Between these plants, the complete association exists (J=0.5). But in case of *B. sindica and C. trilocularis,* the strength of positive interaction shifted from absolute (J=1) to complete (J=0.5). Positive interaction between *B. sindica* and *L. sindicus* can be explained as per niche differentiation model, which suggests that co-existence between the species, occur in order to avoid competition for limited resources. It is further evident from the fact that both species are well adapted for the loose sandy soil. Similarly *L. cristata* and *S. asper* favoured compact/ gravel soil type. On the basis of plant habits and their interaction types, we can conclude that perennial - annual system is more adaptable to the temporal fluctuations as compared to complete seasonal or perennial systems.

**Multivariate Analysis**

Once the association, their types, and strength are established, identification of the limiting factors those underlying the mechanism with such association patterns are prerequisite. Mangold *et al.,* (2004) identified the limiting resources within a semi-arid plant association and they suggested that N is the primary limiting resource for the dominant functional group between *Festuca idahoensis* and *Agropyron spicatum.* In order to determine usefulness of various attributes selected for PCA analysis, the concept of component defining variable (CDV) which stipulates the selection and subsequent naming the variable with the higher component loading (correlation coefficient) as variables that provide the best relationship (Iwara *et al.,* 2011) was employed. The PCA analysis suggesting that there is a relatively higher correspondence between soil, vegetation, community distribution pattern and types of percent significant pairs. The first two principal components (PC1 and PC2) together accounted for 100% of the total variance in data set with their individual contribution being 79.37% and 20.63%, respectively (Fig. 2). Principal components were considered useful if their cumulative percentage of variance approached 80% (Wei-Giang *et al.,* 2008). Most of the parameters are well correlated with axis 1. However, random distribution of community (71%), and Simpson index (56.3%), are correlated with axis 2 (Fig. 2). In present study correlation circle reveled that soil P, electric conductivity, richness, Shannon and Weaver index, distribution types are correlated with nature of association pairs.

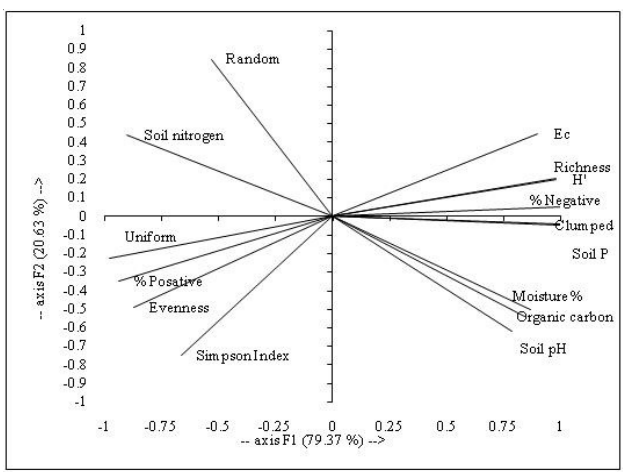


**Figure 2.** Principal Component Analysis

**Table 3.** Statistically significant species pairs during various sampling times

| Associated Plants | Chi square value | Ochiai Index | Dice Index | Jaccard Index |
|---|---|---|---|---|
| | **Pulse Event Positive** | | | |
| *Blepharis sindica - Corchorus trilocularis* | 12 | 1.00 | 1.00 | 1.00 |
| *Blepharis sindica –Justicia simpex* | 5.45 | 0.70 | 0.66 | 0.50 |
| *Blepharis sindica - Lasiurus sindicus* | 5.45 | 0.70 | 0.66 | 0.50 |
| *Corchorus trilocularis - Lasiurus sindicus* | 5.45 | 0.70 | 0.66 | 0.50 |
| *Justicia simplex - Lasiurus sindicus* | 12 | 1.00 | 1.00 | 1.00 |
| *Corchorus depressus - Euphorbia granulata* | 6.0 | 0.81 | 0.80 | 0.66 |
| *Cyprus rotantus - Dactyloctenium aegyptium* | 6.1 | 0.84 | 0.83 | 0.71 |
| *Convolvulus microphyllus - Mimosa indica* | 12 | 1.00 | 1.00 | 1.00 |
| *Euphorbia granulata - Lepidagathis cristata* | 8.4 | 0.89 | 0.88 | 0.80 |
| *Euphorbia granulata - Sonchus asper* | 8.0 | 0.86 | 0.85 | 0.75 |
| *Lepidagathis cristata - Sonchus asper* | 5.6 | 0.77 | 0.75 | 0.60 |
| | **Pulse Event Negative** | | | |
| *Aristida funiculata - Tribulus terrestris* | 7.2 | 0.18 | 0.15 | 0.08 |
| *Blepharis sindica -Tephrosia purpurea* | 5.4 | 0.21 | 0.15 | 0.08 |
| *Cenchrus biflorus - Corchorus depressus* | 6.0 | 0.00 | 0.00 | 0.00 |
| *Corchorus trilocularis - Tephrosia purpurea* | 5.4 | 0.21 | 0.15 | 0.08 |
| *Eragrostis ciliaris - Portulaca oleracea* | 5.4 | 0.00 | 0.00 | 0.00 |
| *Eragrostis ciliaris - Corchorus depressus* | 5.4 | 0.00 | 0.00 | 0.00 |
| *Justicia simplex - Tephrosia purpurea* | 12 | 0.00 | 0.00 | 0.00 |
| *Lasiurus sindicus - Tephrosia purpurea* | 12 | 0.00 | 0.00 | 0.00 |
| | **Inter Pulse Event Positive** | | | |
| *Blepharis sindica - Cenchrus biflorus* | 5.4 | 0.70 | 0.66 | 0.50 |
| *Blepharis sindica - Citrullus colocynthis* | 5.4 | 0.70 | 0.66 | 0.50 |
| *Blepharis sindica - Corchorus trilocularis* | 7.2 | 0.81 | 0.80 | 0.66 |
| *Blepharis sindica - Lasiurus sindicus* | 5.4 | 0.70 | 0.66 | 0.50 |
| *Cenchrus biflorus - Lasiurus sindicus* | 12 | 1.00 | 1.00 | 1.00 |
| *Lepidagathis cristata - Sonchus. asper* | 7.2 | 0.81 | 0.80 | 0.66 |
| *Chenopodium album - Corchorus depressus* | 12 | 1.00 | 1.00 | 1.00 |
| | **Inter Pulse Event Negative** | | | |
| *Blepharis sindica - Tephrosia purpurea* | 5.4 | 0.21 | 0.15 | 0.08 |
| *Lasiurus sindicus - Tephrosia purpurea* | 12 | 0.00 | 0.00 | 0.00 |
| | **Non Pulse Event Positive** | | | |
| *Blepharis sindica - Lasiurus sindicus* | 5.4 | 0.70 | 0.66 | 0.50 |
| *Lasiurus sindicus - Chloris viscosa* | 12 | 1.00 | 1.00 | 1.00 |
| *Chloris viscosa - Chloris virgata* | 12 | 1.00 | 1.00 | 1.00 |
| *Eragrostis ciliaris - Lepidagathis cristata* | 7.2 | 0.81 | 0.80 | 0.66 |
| *Dactyloctenium aegyptium - Lepidagathis cristata* | 5.4 | 0.70 | 0.66 | 0.50 |
| *Lepidagathis cristata - Sonchus. asper* | 5.4 | 0.70 | 0.66 | 0.50 |

**Path Analysis**

Regression analysis revealed that soil pH and electric conductivity are significantly and negatively affecting the random ($r=1.00$, $P<0.01$) and uniform ($r=1.00$, $P<0.01$) distribution of community in quadratic fashions, respectively (Table 4). However soil phosphorus is linearly and positively affecting clumped distribution ($r=1.00$, $P<0.01$). Species richness also supported clumped pattern but in exponential fashion ($r=0.99$, $P<0.05$).

Diversity parameters like species richness ($r=0.99$, $P<0.05$) and Shannon and Weaver ($r=0.99$, $P<0.05$), negatively and linearly related with uniform pattern. In return this uniform distribution linearly and positively affecting % of positive pair association ($r=0.99$, $P<0.05$). However, richness ($r=0.99$, $P<0.05$) and Shannon and Weaver ($r=0.99$, $P<0.05$) negatively related with % of positive pair association in exponential fashion, while both these parameters supporting % of negative pair association ($r=1.0$, $P< 0.01$) in quadratic fashion.

**Table 4.** Path analysis between various independent and dependent variables

| Independent Variables | Dependent Variables | Type of Relationships | Equation |
|---|---|---|---|
| Soil Ph | Random Distribution | Quadratic | Random Distribution = 2420.85-385.31soil Ph +15.37soil Ph$^{\wedge 2}$, r = 1.00** |
| Electric Conductivity | Uniform Distribution | Quadratic | Uniform distribution = -208.78+2040.38 Electric Conductivity+-3769.18 Electric Conductity$^{\wedge 2}$, r 1.0** |
| Soil P | Clumped Distribution | Linear | Clumped Distribution = -180.93+6.41Soil P, r = 1.0** |
| Richness | Clumped distribution | Exponential | Clumped distribution = 21.01e$^{\wedge(0.153\ Richness)}$, r = 0.997* |
| Richness | Uniform Distribution | Linear | Uniform distribution = 61.48+-5.99 Richness, r = 0.999** |
| Shannon Weaver Index | Uniform Distribution | Linear | Uniform distribution = 105.47+-49.77 Shannon Weaver Index, r = 0.999* |
| Electric Conductivity | % Positive Pair | Linear | % Positive pair = 32.59+- 51.14Electric Conductivity, r = 0.997* |
| Richness | % Positive Pair | Exponential | % Positive pair = 21.97e$^{\wedge(-0.07 Richness)}$, r = 0.997* |
| Shannon Weaver Index | % Positive Pair | Exponential | % Positive pair = 37.33e$^{\wedge(-0.59\ Shannon\ weaver\ Index)}$, r = 0.997* |
| Evenness | % Positive Pair | Quadratic | % Positive pair = -45.50+96.72Evenness+-33.40 Evenness^2, r = 1.0** |
| Uniform Distribution | % Positive Pair | Linear | % Positive Pair = 10.13+0.188 % Positive Pair, r = 0.999* |
| Clumped Distribution | % Negative Pair | Quadratic | % Negative pair = -3.106+0.13Clumped distribution +-0.0004 clumped distribution $^{\wedge 2}$, r = 1.0** |
| Soil P | % Negative Pair | Quadratic | % Negative pair = -43.08+1.97 soil P+-0.019 soil P$^{\wedge 2}$,r = 1.0** |
| Richness | % Negative Pair | Quadratic | %Negative pair = -0.11+0.17Richness+0.043 Richness $^{\wedge 2}$, r =1.00** |
| Shannon Weaver Index | % Negative Pair | Quadratic | % Negative pair = 0.47+-3.08 Shannon weaver index +2.69 Shannon Weaver Index $^{\wedge 2}$, r =1.0** |
| Uniform Distribution | % Negative Pair | Quadratic | % Negative Pair = 6.36+-0.18 Uniform distribution +0.001Uniform distribution$^{\wedge 2}$, r 1.00** |

* P > 0.05; **P > 0.01

Among the soil factors electric conductivity, negatively and linearly associated with % of positive association pair (r=0.99, P<0.05) while, soil phosphorus supports % of negative association pair (r=1.0, P<0.01) in quadratic fashion. Clumped and uniform distribution also affected the % of negative association pair in quadratic fashion but in positive and negative manner, respectively (Table 4). This path analysis revealed that as the richness and Shannon and Weaver Index decreased it facilitate the uniform pattern distribution which in return favors number of significant per cent positive pair. Through this mechanism we can answer our question that deals with the higher number of positive pair during non-pulse season. This finding can be corroborated with the study of Tielborger and Kadmon (2000) who found that the importance of facilitation increases during abiotic stress while negative interaction prevails under benign condition.

Among soil parameters electric conductivity also affecting the uniform pattern of distribution thus indirectly affecting per cent number of positive pair, however, soil phosphorus could be use as a indicator factors that facilitates % of number of significant negative pairs.

## Conclusion

Association analysis is especially useful to gain insight into the mechanism of successional process, further selection of species composition is going on thorough the ‘sieve’ of inter-specific relation during succession (Margoczi, 1995). In addition to the advantages of detecting species interactions in the ecology of the species, determination of inter-specific interaction may be useful for restoration and improvement of ecosystems. Based on the view that the existence of a variety of species can enhance ecosystems functions and services, adaptable species can be simultaneously selected for reclamation of ecosystems, especially if these species are positive in association and covariation. In arid and semi arid environments with harsh environmental conditions, simultaneously selecting herbs and woody annual, and in particular those with both have a positive association (as was detected in the case of *B. sindica* and *L. sindicus* in this study) will enhance the chances of success in landscape management strategies. Both species viz., *B. sindica –L. sindicus* can be recommended for the long term habitat stability, forage availability, and grassland management in the semi arid areas of Indian Thar Desert. The present study provides useful information about the association types and the strength of interaction between herbaceous species. Richness, Shannon and Weaver index, electric conductivity and soil phosphorus were recognized as indicator factor that controlling the types of associations. Within arid and semi arid region of the Thar Desert of the India these factors can be utilized for desire types of pairing between herbaceous component.

**Acknowledgements**:
The authors are grateful to Professor and Head, Department of Botany, Jai Narain Vyas University, Jodhpur, for facilities and to the Director, CAZRI, Jodhpur for study leave.

**References**

Ahmad, I., M. Hussain, M. Sajid, A. Ahmad and M. Hameed. 2008. Spatio-temporal effect on association of plant species in Soon valley of Pakistan. *Pak. J. Bot.* 40 (5): 1865-1876.

Bharucha, F. R. 1975. Plant association in western Rajasthan. In: R.K. Gupta, and I. Prakash (eds.). *Environmental analysis of the Thar Desert*. Dehradun: English Book Depot, India, pp. 274-297.

Callaway, R. M. 1994. Facilitative and interfering effects of *Arthrocnemum subterminale* on winter annuals in a California salt marsh. *Ecology* 75: 681-686.

Callaway, R. 1995. Positive interaction among plants. *Bot. Rev.* 61: 306-349.

Fajardo, A., C. L. Quiroz, L. A. Cavieres. 2008. Spatial patterns in cushion-dominated plant communities of the high Andes of central Chile: how frequent are positive associations?. *J. Veg. Sci.* 19: 87-96.

Getzin, S., C. Dean, F. He, J. A. Trofymow, K. Wiegand, T. Wiegand. 2006. Spatial patterns and competition of tree species in a Douglas-fir chronosequence on Vancouver Island. *Ecography* 26: 671-682.

Hubalek, Z. 1982. Coefficients of association and similarity, based on binary (presence-absence) data: an evaluation. *Biol. Rev.* 57: 669-689.

Iwara, A. I., F. O. Ogundele, U. W. Ibor and T. N. Deekor. 2011. Multivariate analysis of soil-vegetation interrelationship in a south-southern secondary forest of Nigeria. *Int. J. Bio.* 3: 73-82.

Janson, S. and J. Vegelius. 1981. Measures of ecological association. *Oecologia* 49: 371-376

Jochen, S. H. and M. E. Bruce. 2002. Positive and negative plant interactions contribute to north-south patterned association between two desert shrub species. *Oecologia* 132: 402-410.

Kent, M. and P. Cooker. 1992. *Vegetation description and analysis.* Bekhaven Press, London.

Le Houerou, R. L. Bingham and W. Skerbek. 1988. Relationship between the variability of production and the variability of annual precipitation in world arid lands. *J. Arid. Environ.* 15: 1-18.

Ludwig, J. A. and J. F. Reynold. 1988. *Statistical Ecology: A primer on methods and computing*. John Wiley and sons, New York. 339 p.

Mangold, J. K., R. Sheley, J. Jacobsen, T. Svejcar and C. Zabinski. 2004. Identification of the limiting resources within a semi-arid plant association. *J. Arid Environ.* 58: 309-320.

Margoczi, K. 1995. Inter-specific association in different successional stage of the vegetation in a Hungarian sandy area. *Tiscia.* 29: 19-26.

Noy-Meir, I. 1973. Desert ecosystem: Environment and producers. *Annu. Rev. Ecol. Syst.* 4: 25-41.

Sanjerehei, M. M., M. Jafari, A. Mataji, N. B. Meybodi and M. R. Bihamta. 2011. Facultative and competitive interaction between plant species (an example from Nodushan ranglangs, Iran). *Flora* 206: 631-637.

Sen, D. N. 1966. Ecology of the Indian desert 1. On the phytosociology of the vegetation of Jodhpur. *Trop. Ecol.* 7: 136-152.

Tielborger, K. and R. Kadmon. 2000. Temporal environmental variation tips the balance between facilitation and interference in desert plant. *Ecology* 81: 1544-1553.

Turner, S. J. A. R. Johnson, and W. G. Whitford. 2004. Pairwise species associations in the perennial vegetation of the Northern Chihuahuan Desert. Southwestern *Naturalist* 49(1): 1-10.

Wei-Giang, Li., L. Xiao-Jing, K. Ajmal and G. Bilquees. 2008. Relationship between soil characteristics and halophytic vegetation in coastal region of north china. *Pakistan J. Bot.* 403: 1081-1090.

Wootton, T. J. and M. Emmerson, 2005. Measurement of interaction strength in nature. *Annu. Rev. Ecol. Evol. Syst.* 36: 419-444.